



Operational Data on Crew Exposure to Mild Hypobaric Hypoxia in Microgravity

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Disclosure Information

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Jason Norcross

I have no financial relationships to disclose.

I will not discuss off-label use and/or investigational use
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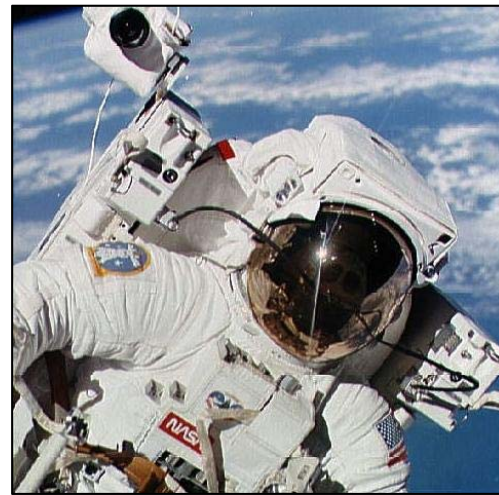
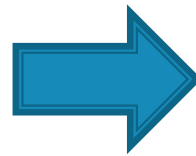
Background



- Extravehicular Activity (EVA) is vital to human exploration of space.
- The pressure differential between the internal cabin and the spacesuit introduces the risk of Decompression Sickness (DCS).



14.7 psia



4.3 psia

Background



- Risk of DCS is currently reduced by lengthy prebreathe protocols
 - Preparation for an EVA takes 5-6 hours.
 - Low Work Efficiency Index (WEI ~ 0.4 for ISS)
 - $WEI = \text{Total EVA time} / \text{Total EVA Overhead}$
- To reduce the risk of DCS and denitrogenation time, an intermediate habitat environment of 8.0 psia and 32% O₂ was recommended for NASA's future exploration missions (NASA/TP-2010-216134)
- Estimated to reduce prebreathe time to 15 min while maintaining predefined levels of acceptable DCS risk



Updated Intermediate Atmosphere



- Exploration Atmospheres Action Team 2012
Recommendation: 8.2 psia and 34% Oxygen
- Compared to 8/32
 - Hypoxic stress reduced
 - Flammability still acceptable
 - No change in DCS risk

$$P_{IO_2} = (P_B - P_{H_2O}) \times FiO_2$$

P_B (psia)	$O_2\%$	pp O_2 (mmHg)	P_{IO_2} (mmHg)	EAA (ft)	pp N_2 (mmHg)
8.0	32	132	117	6170	281
8.2	34	144	128	3980	280
Difference		+12	+11	-2190	-1

Hypoxic Spaceflight Experience



- Shuttle Staged Denitrogenation Protocol
 - Exposed crew to 10.2 psia and 26.5% O₂

P _B (psia)	O ₂ %	ppO ₂ (mmHg)	P _i O ₂ (mmHg)	EAA (ft)	ppN ₂ (mmHg)
10.2	26.5	140	127	4150	388
8.2	34	144	128	3980	280
Difference		+4	+1	-170	-108

Comparison of the Shuttle staged condition with the proposed Exploration Atmosphere



Are there any physiologic differences between crew members exposed to the Shuttle staged protocol vs. those that were not?

Data Mining Sources

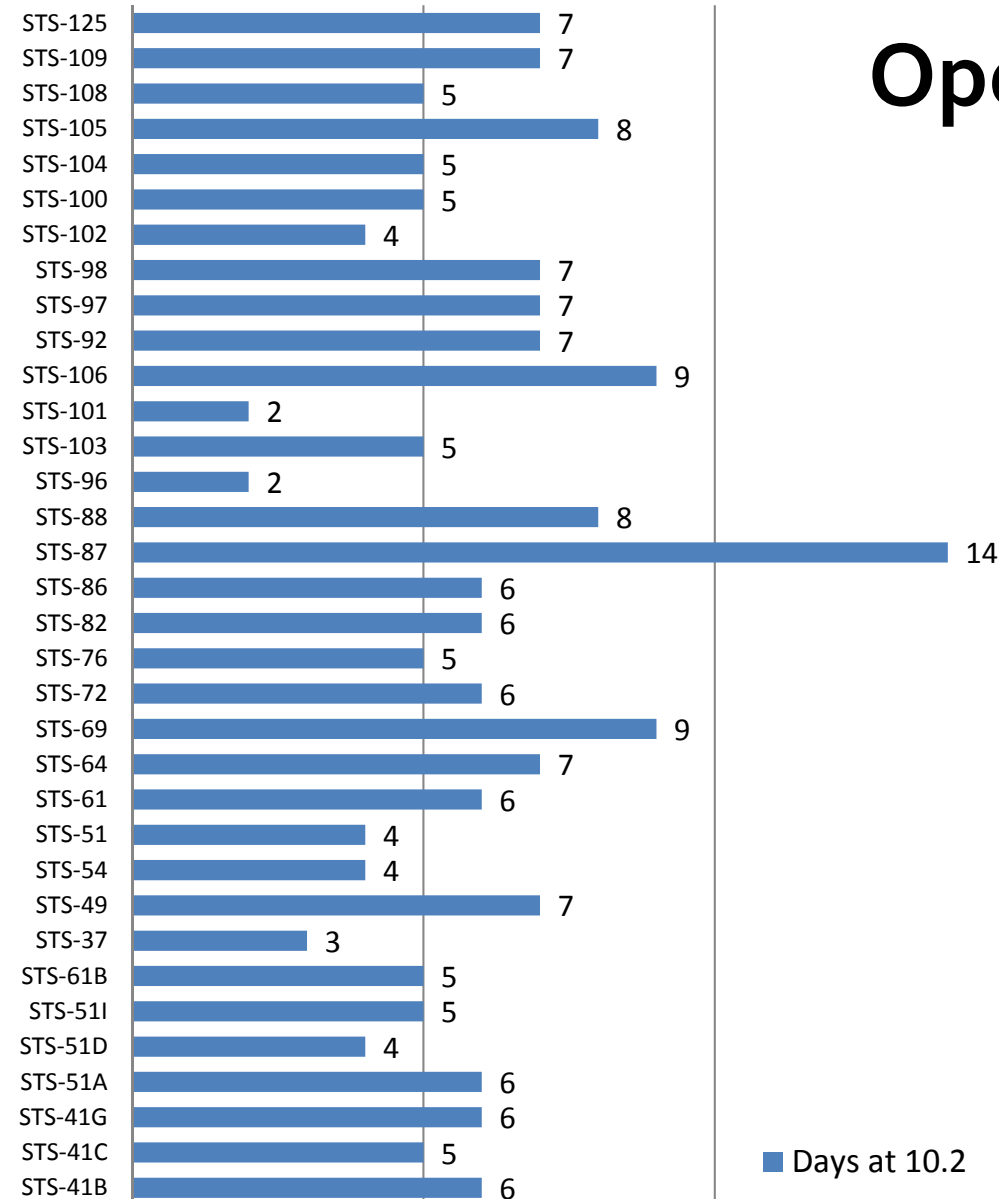


- Operational Prebreathe Database
 - Internal NASA database maintained by the JSC EVA Physiology Lab
 - EVA dates and PB protocol used
- Life Sciences Data Archive (LSDA)
 - Data from research studies performed for other purposes
- Lifetime Surveillance of Astronaut Health (LSAH)
 - Symptomatic complaints documented in the Shuttle Program Postflight Medical Debriefs



Operational Experience Times

- 34 Shuttle missions operated at the staged condition
 - 202 days
 - 1,252 man-days
- Assumed that shuttle depressed on flight day 2 and repressed on the day following the last EVA
- Most missions were depressed for 5-7 days



LSDA/LSAH Data Mining Efforts



- Developed a prioritized list of measurements of interest for exposure to HH using a systems based approach.
 - Symptomatic Complaints
 - Shortness of breath
 - Headache
 - Lethargy/Malaise
 - Sleep disturbances
 - Nausea/vomiting
 - Dizziness
 - Confusion/Disorientation
 - Appetite Changes
 - Vital Signs
 - Heart Rate
 - Blood Pressure
 - Pulse Oximetry
 - Respiratory Rate
 - Blood Work
 - CBC
 - Chemistries
 - Cognitive Studies
 - Physical Exam Findings

LSDA Data Mining



- Compiled a list of all LSDA studies performed for any Shuttle mission
- Prioritized list by number of missions exposed to the staged condition
 - 112 LSDA studies were performed during at least one mission of interest
 - 19 studies were performed for 3 or more missions

LSDA Study Name	Number of Missions Exposed to 10.2
Space Flight and Immune Function (DSO 498)	13
Monitoring Latent Virus Reactivation and Shedding in Astronauts (DSO 493)	10
The Effects of Prolonged Space Flight on Head and Gaze Stability During Locomotion (DSO 614)	8
Visual-Vestibular Integration (DSO 604)	7
Individual Susceptibility to Postflight Orthostatic Hypotension (DSO 496)	6
Back Pain Pattern in Microgravity (DSO 483)	5
Postural Equilibrium Control During Landing/Egress (DSO 605)	5
Clinical Characterization of Space Motion Sickness (SMS) (DSO 455)	4
Interaction of the Space Shuttle Launch and Entry Suit and Sustained Weightlessness on Egress Locomotion (DSO 331)	4
Orthostatic Function During Entry, Landing, and Egress (DSO 603)	4
Validation of Predictive Tests and Countermeasures for Space Motion Sickness (DSO 401)	4
Cardiovascular and Cerebrovascular Responses to Standing Before and After Space Flight (DSO 626)	3

LSDA Data Mining



- Compiled a list of measurements taken for each LSDA study performed on 2 or more missions of interest.
- A final prioritized list of LSDA studies was developed based on physiologic relevance and number of available subjects.
 - High Priority
 - Moderate Priority
 - Low Priority
 - Not applicable

LSDA Data Mining – Current Status



- Investigating “high priority” list
 - Available data is being compiled and de-identified
- Several current studies of interest
 - Cardiovascular and Cerebrovascular Responses to Standing Before and After Space Flight (DSO 626)
 - Plasma volume, red cell volume, total blood volume
 - Measurements taken at L-20, L-10, R+0, and R+3
 - Sleep-Wake Actigraphy and Light Exposure During Spaceflight (DSO 634)
 - Alertness, number of awakenings, sleep disturbance, sleep latency, sleep quality, sleep time
 - Inflight Aerobic Exercise (DSO 476)
 - Aerobic capacity, blood pressure, heart rate, hematocrit, etc.
 - Monitoring Latent Virus Reactivation and Shedding in Astronauts (DSO 493) and Space Flight and Immune Function (DSO 498)
 - Viral shedding studies with large “N”

Forward Work



- LSDA
 - Continue mining efforts for individual studies
 - Expect data from 3 “high priority” studies
 - Proceed to “moderate priority” list of studies
- LSAH
 - Completed listing of the incidence of symptomatic complaints pending
- Data analysis will reveal whether or not significant physiologic differences are seen
- Chamber studies of proposed 8.2/34 environment to investigate PB requirements for DCS prevention and characterize the hypoxic stress

Thank You



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Operational Experience Table – Back Up

Flight	Launch	Landing	Crew Size	Last EVA	Days at 10.2/26.5	Man Days at 10.2/26.5
STS-41B	2/3/1984	2/11/1984	5	2/9/1984	6	30
STS-41C	4/6/1984	4/13/1984	5	4/11/1984	5	25
STS-41G	10/5/1984	10/13/1984	7	10/11/1984	6	42
STS-51A	11/8/1984	11/16/1984	5	11/14/1984	6	30
STS-51D	4/12/1985	4/19/1985	7	4/16/1985	4	28
STS-51I	8/27/1985	9/3/1985	5	9/1/1985	5	25
STS-61B	11/26/1985	12/3/1985	7	12/1/1985	5	35
STS-37	4/5/1991	4/11/1991	5	4/8/1991	3	15
STS-49	5/7/1991	5/16/1992	7	5/14/1992	7	49
STS-54	1/13/1993	1/19/1993	5	1/17/1993	4	20
STS-51	9/12/1993	9/22/1993	5	9/16/1993	4	20
STS-61	12/2/1993	12/13/1993	7	12/8/1993	6	42
STS-64	9/9/1994	9/20/1994	6	9/16/1994	7	42
STS-69	9/7/1995	9/18/1995	5	9/16/1995	9	45
STS-72	1/11/1996	1/20/1996	6	1/17/1996	6	36
STS-76	3/22/1996	3/31/1996	6	3/27/1996	5	30
STS-82	2/11/1997	2/21/1997	7	2/17/1997	6	42
STS-86	9/25/1997	10/6/1997	7	10/1/1997	6	42
STS-87	11/19/1997	12/5/1997	6	12/3/1997	14	84
STS-88	12/4/1998	12/15/1998	6	12/12/1998	8	48
STS-96	5/27/1999	6/6/1999	7	5/29/1999	2	14
STS-103	12/19/1999	12/27/1999	7	12/24/1999	5	35
STS-101	5/19/2000	5/29/2000	7	5/21/2000	2	14
STS-106	9/8/2000	9/20/2000	7	9/17/2000	9	63
STS-92	10/11/2000	10/24/2000	7	10/18/2000	7	49
STS-97	11/30/2000	12/11/2000	5	12/7/2000	7	35
STS-98	2/7/2001	2/20/2001	5	2/14/2001	7	35
STS-102	3/8/2001	3/21/2001	7	3/12/2001	4	28
STS-100	4/19/2001	5/1/2001	7	4/24/2001	5	35
STS-104	7/12/2001	7/24/2001	5	7/17/2001	5	25
STS-105	8/10/2001	8/22/2001	7	8/18/2001	8	56
STS-108	12/5/2001	12/17/2001	7	12/10/2001	5	35
STS-109	3/1/2002	3/12/2002	7	3/8/2002	7	49
STS-125	5/11/2009	5/24/2009	7	5/18/2009	7	49
Total					202	1252